EFFECT OF FINGER MILLET SUPPLEMENTATION ON APPETITE REGULATING HORMONES, MENTAL HEALTH AND COGNITIVE PERFORMANCE IN MALE ATHLETES

SHORT SYNOPSIS

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Certificate

I hereby declare that the short synopsis **"EFFECT OF FINGER MILLET SUPPLEMENTATION ON APPETITE REGULATING HORMONES, MENTAL HEALTH AND COGNITIVE PERFORMANCE IN MALE ATHLETES"** being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in Nutrition and Dietetics under School of Allied Health Sciences of Manav Rachna International Institute of Research & Studies, Faridabad during the academic year 2024-2025.

It is a bona fide record of original work carried out under the supervision of Dr. Kommi Kalpana and has not been submitted in full or part to any other university or institute for degree or diploma.

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ABSTRACT

The prolonged deprivation of dietary fibre, coupled with nutrient deficiencies and persistent stress leads to low levels of leptin hormone. This imbalance can cause the body to produce too much of the hunger hormone ghrelin and stress hormone cortisol. This hormonal imbalance fosters maladaptive behaviours such as emotional eating and food cravings, exacerbates irritability and compromises mental and cognitive performance among athletes. Finger millet is known to have functional properties that help prevent many health problems such as insulin resistance, high blood pressure, cancer and cardiovascular diseases increasing the period of gastric emptying and providing roughage to the gastro intestine. However, the health benefits of finger millet have not been explored in the athletic population. Hence, the present randomized control trial aims to study the effect of finger millet supplementation on appetite-regulating hormones, mental health and cognitive performance in male athletes. Athletes (n=30) and non-athletes (n=30) aged between 18-25 years would be recruited through convenient purposive sampling. Baseline information such as socio-demographic profile, anthropometry and 3 days dietary intake will be recorded. The participants will be asked to refrain from exercise in the previous 24 hours and report to the laboratory after an 8-12-hour fast on the day of the experiment. Upon reporting to the lab, a fasting blood sample will be taken for the assessment of serum ghrelin, leptin and cortisol levels. Then the participants will be asked to consume an ad-libitum breakfast (rice/wheat). A blood sample will again be collected at 120 mins and 180 min of the fed state to assess the hormones. Subjective appetite/satiety will also be assessed through the Visual Analogue Scale (VAS) on these time stamps. Information on mental health and cognitive performance questionnaires will also be collected in a well-fed state. Based on the baseline information, both the athlete group (AG; n=30) and non-athlete group (NAG; n=30) will be further randomly assigned to the experimental group and the control group. AG will be assigned to Athlete Control group (CGA; n=15) and Athlete Finger Millet Supplementation Group (EGA; n=15). NAG will be assigned to Non-Athlete Control group (CGNA; n=15) and Non-Athlete Finger Millet Supplementation Group (EGNA; n=15). Finger-millet products (1/3rd of the daily cereals will be replaced by finger millet) will be given to EGA and EGNA and rice /wheat-based diet to the CGA and CGNA for 60 days. End-line information will be collected following similar procedures of baseline on anthropometry, nutrient intake, biochemical samples

of serum ghrelin, leptin and cortisol, subjective appetite, mental health and cognitive performance.

Keywords: Finger Millet, Appetite Hormones, Mental health, Cognitive Performance, Athletes

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I. INTRODUCTION

Ghrelin and leptin are two major hormones that regulate appetite. Ghrelin is a hunger hormone that induces hunger and increases appetite while Leptin is a satiety hormone that suppresses the appetite and induces the feeling of fullness and satiated. The brain's immediate reaction to stress is the pursuit of rapid hedonic gratification. In doing so, it orchestrates cravings for high-caloric simple carbohydrates, often categorized as 'reward foods,' as an expedient means to promptly satisfy glucose demands and elicit the immediate release of dopamine, the 'feel-good' hormone *(Clemente-Suarez et al., 2022).*

Glucose supply in the body triggers insulin production for the uptake of glucose by the cells. As soon as the body receives glucose the released dopamine hormone suppresses the stress hormone cortisol and revives the body from the state of stress *(Abizaid, 2009).* The ingestion of surplus glucose derived from processed and calorically dense nutritional sources imposes a metabolic burden, precipitating an overproduction of insulin. This, in turn, fosters the development of insulin resistance, thereby contributing to weight gain and the onset of metabolic disorders. This metabolic perturbation compounds the physiological strain and prompts the release of stress-related hormones. Subsequent to the dopamine's wane, cortisol levels ascend once more. High-calorie dietary items are known to accentuate cortisol production due to the substantial metabolic demands they impose in response to elevated blood glucose concentrations. This metabolic strain can additionally precipitate organ damage *(Rahati et al., 2022).* In response to stress, the central nervous system initiates a neurobiological cascade involving the stimulation of appetite and the secretion of ghrelin, ultimately culminating in a dopamine-mediated gratification response to food consumption. This recurring sequence perpetuates itself, culminating in deleterious outcomes such as emotional overeating, eating disorders, and adverse impacts on mental health and cognitive functioning, particularly in the context of athletic performance. It is imperative to interrupt and supplant this detrimental loop with more health-conscious and enduring alternatives *(Yau and Potenza, 2013).*

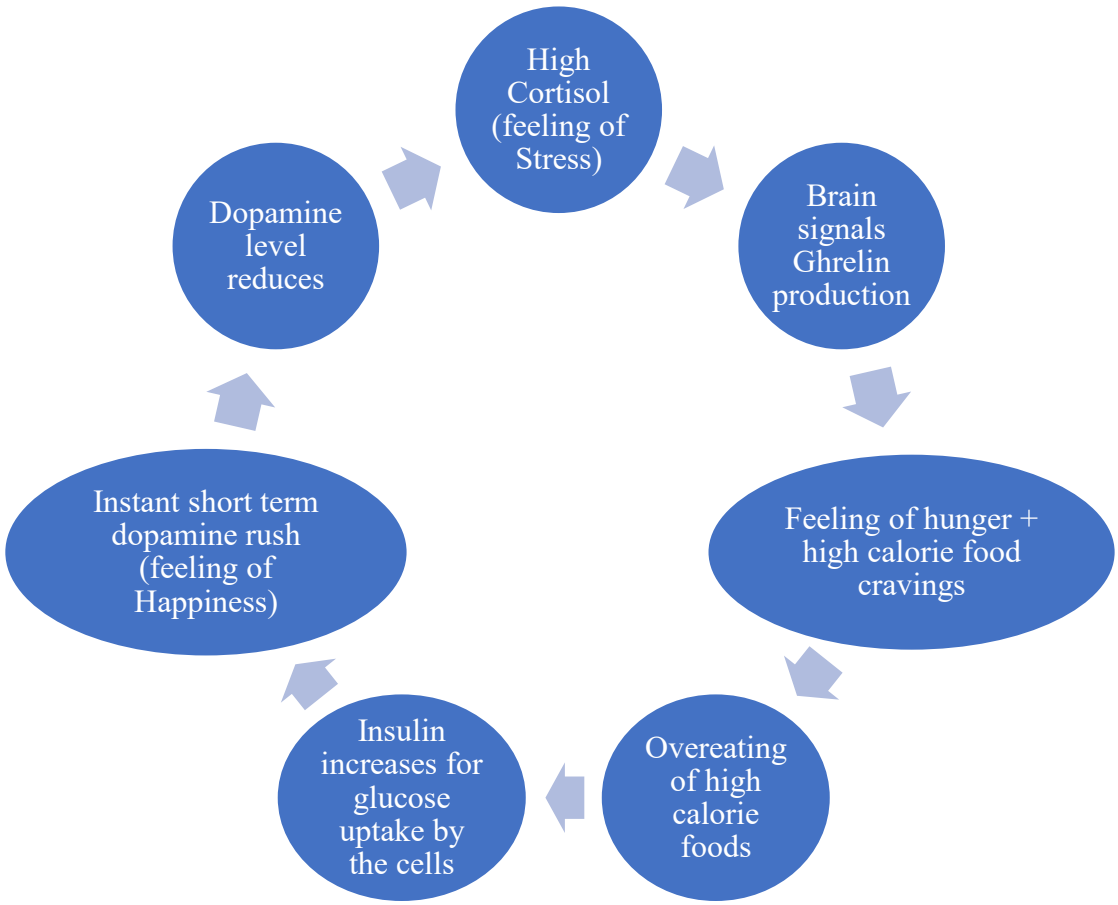

High Cortisol (feeling of Stress)
Brain signals Ghrelin production
Feeling of hunger + high calorie food cravings
Overeating of high calorie foods
Insulin increases for glucose uptake by the cells
Instant short term dopamine rush (feeling of Happiness)
Dopamine level reduces

Figure 1. Hormonal Regulation of Appetite

Ingesting a diet rich in high-fibre content, nuts, low-fat options, reduced sugar and salt, low-calorie, complex carbohydrates, high-protein sources, polyunsaturated fatty acids (PUFA), freshly prepared dishes, and nutrient-dense foods fosters the secretion of leptin hormone. Leptin, in turn, confers a sustained sense of satiety and fullness over an extended duration *(Ge et al., 2020; Zhang et al., 2016; Kratz et al., 2002).* High leptin levels increase the slow-releasing but long-term production of happy hormones- dopamine and serotonin which provide the feeling of happiness and satisfaction for a long duration. Leptin combined with dopamine and serotonin (happy hormones) keeps down the cortisol (stress hormone) levels *(Brown et al., 2016; Burghardt et al., 2012).*

Mental Health of Athletes

Athletes often grapple with insufficient financial backing for training and performance, as well as limited income prospects. Only a minority of athletes can secure stable employment and

substantial earnings from their athletic pursuits. The intense competition, elevated risk of serious sports-related injuries, and the inherent instability of an athletic career dissuade many parents from encouraging their children to pursue sports as a viable career path *(Kovacs et al., 2022).*

There tends to be a prevailing emphasis, both from the athletes themselves and their trainers, on the physical well-being of athletes, with the mental aspect of health often receiving insufficient attention. Even in contemporary times, mental health continues to be regarded as distinct from physical health, rather than being recognized as an integral component of overall well-being. Various factors such as negligence, over-training, pressure to perform, confidence, nervousness, winning, competition, physical injuries, physical pressure, family pressure, financial pressure, homesickness etc. contribute predominantly to deteriorating the mental health of athletes *(Rice et al., 2016).*

Cognitive Performance of Athletes

The cognitive proficiency of each athlete not only impacts their performance but also contributes substantively to the overall team performance. Consequently, cognitive functions such as concentration, alertness, attention, critical thinking, decision-making, problem-solving, memorization, timing, and interpersonal coordination assume a decisive role, influencing the game's outcome through the orchestration of athlete skills, team synergy, and mutual understanding *(Baker et al., 2014).*

Millets

Millets are small-seeded crops that have a very short growing season and can grow in dry and high-temperature regions. Millets are the traditional staple food of dry land areas around the world. India is one of the top producers of millet in the world. Due to India's versatile and fertile land, it can produce various kinds of millet in various areas. There are various kinds of millet such as Sorghum, Pearl Millet, Finger Millet, Foxtail Millet, Common Millet, Little Millet, Barnyard Millet and Kodo millet *(Rao et al., 2017).* Millets are considered nutri-cereals as these are rich in protein, essential fatty acids, dietary fibre, B-vitamins, and minerals such as calcium, iron, zinc, potassium and magnesium *(Saleh, 2013).*

Nutrient Profile of Millets

Millets are considered nutri-cereals as these are rich in protein, essential fatty acids, dietary fibre, B-vitamins, and minerals such as calcium, iron, zinc, potassium and magnesium *(Saleh, 2013).* The extraordinary nutritional profile and health benefits have brought these up again in the market and have caught everyone's attention. With the right awareness millet and other traditional foods and recipes that were lost for some times have now again found their place in our diets and are being adopted rapidly.

Finger millet

Finger Millet (Eleusine coracana) is an annual grass with up to 170 cm of height. It is a staple food in Africana and south Asian countries. It is also commonly known as Ragi (in Kannada), Nachni (in Marathi) and Mandua (in Bengali). Finger millet is a highly nutrient-dense, versatile and easy-to-digest crop. It is the richest source of calcium (364mg/100g) as compared to other millets. 100 g of the edible portion of Finger millet contains 10.89g moisture, 7.16g protein, 1.92g fat, 11.18g dietary fibre, 66.82g carbohydrate, 1342KJ energy, 0.37mg thiamine (Vitamin B1), 0.17mg riboflavin (Vitamin B2), 1.34mg niacin (Vitamin B3), 0.29mg pantothenic acid (Vitamin B5), 0.05mg total Vitamin B6, 0.88ug biotin (Vitamin B7), 34.66ug folate (Vitamin B9), 41.46ug vitamin D2 (Ergocalciferol), 0.16mg vitamin E (Tocopherol), 3ug vitamin K1 (Phylloquinone), 154ug total carotenoids, 364mg calcium, 4.62mg iron, 146mg magnesium, 3.19mg manganese, 210mg phosphorus, 443mg potassium, 4.75 mg sodium and 2.53 mg zinc (*Rao et al., 2017*). It can be consumed in various ways such as boiled, flour, porridge, baked, roasted, milled, malted, popped, fermented, decorticated and super nutritious sprouted form (*Shobana, 2013*).

Health Benefits of Finger Millet

Finger millet is rich in calcium which is beneficial in dealing with calcium and vitamin D deficiency. It helps in maintaining bone health and reduces the risk of osteoporosis and fractures (*Ambati, 2019*). Antioxidants of finger millet could help protect from oxidative, inflammatory and physiological stress (*Amadou, 2013*). The abundant fibre content in millets intricately moderates the rate of gastric emptying, facilitating thorough digestion, absorption, and metabolic processing of ingested food. Consequently, this gradual release of carbohydrates into the

bloodstream promotes the maintenance of stable blood sugar levels and the precise regulation of insulin production to facilitate efficient cellular glucose uptake (*Almaski, 2022*). This prevents the excess production of cortisol and ghrelin hormone which helps in controlling appetite and managing weight and blood sugar levels (*Ramashia, 2019*).

It increases the transit time of food in the gut which helps in reducing inflammatory bowel disease (*Thapliyal and Singh, 2015*). The bile acid and steroid binding properties of finger millet prevent the risk of cardiovascular diseases. It fastens wound healing (*Amadou, 2013*), and has antidiabetic and anti-ulcerative properties (*Devi, 2011*). Its germinated form improves haemoglobin levels and reduces serum cholesterol and triglycerides levels. It improves satiety by decreasing ghrelin and cortisol hormones and thereby weight loss was observed (*Yousseif, 2013).*

II. RATIONALE OF THE STUDY

Prolonged lack of consumption of fibre and persistent stress leads to the excess production of hunger and stress hormones i.e., ghrelin and cortisol. That in excess results in emotional eating, food cravings, irritability, and deteriorating mental and cognitive performance. Hunger (ghrelin hormone) creates a state of stress in the body which is initiated by the release of cortisol hormone. Cortisol increases the cravings for high-calorie simple carbohydrate foods or reward foods to instantly meet glucose needs. Glucose supply in the body triggers insulin production for glucose uptake thereby releasing of dopamine hormone, suppressing of stress hormone cortisol and reviving the body from the state of stress.

Mental health is highly correlated with physical health and contributes to a major part of overall health. Factors such as negligence, over-training, pressure to perform, confidence, nervousness, winning, competition, physical injuries, physical pressure, family pressure, financial pressure, homesickness etc. contribute predominantly to deteriorating the mental health of athletes. This pressure can have a deteriorating effect on their overall health, especially mental health. Mental pressure, over-physical exertion and lack of adequate nutrition in athletes can lead to a downfall in their athletic and cognitive performance such as poor concentration, confusion, lethargy, alertness and planning etc.

Finger millet is a highly nutritious, functional food that is rich in antioxidants. It contains the highest concentration of calcium among all other millets and could prove to be beneficial in dealing with calcium and vitamin D deficiency in athletes while enhancing their bone strength and performance. The high fibre content in finger millet will provide satiety to the athletes and will help in managing eating disorders and food cravings in them. The high nutritional profile along with the high fibre content leads to the slow release of nutrients especially carbohydrates into the blood and help in maintaining blood sugar level, regulating appropriate insulin production for the glucose uptake by the cells and providing energy for longer duration. This prevents the excess production of cortisol and ghrelin hormone that helps in controlling appetite and managing weight and blood sugar levels. The effect of millet intervention among athletes on their stress level, mood, behaviour and cognitive performance by analysing the changes in the hormonal system in the body are scanty. The present research study aims to focus on the effect of

finger millet products on appetite regulating hormones, mental health and cognitive performance in male athletes.

III. RESEARCH QUESTIONS

1. Does the finger millet supplementation have an effect on the appetite-regulating hormones (ghrelin, leptin, cortisol) in male athletes?
2. Does finger millet supplementation have an effect on the mental health status and cognitive performance of male athletes?
3. What is the association between appetite regulating hormones, mental health and cognitive performance with finger millet supplementation in male athletes?
4. What is the comparative impact of finger millet supplementation in male athletes and non-athletes?

IV. RESEARCH OBJECTIVES

1. To study the acceptability of finger millet products among male athletes.
2. To evaluate the effect of finger millet supplementation on appetite-regulating hormones (ghrelin, leptin, cortisol) in male athletes.
3. To assess the effect of finger millet supplementation on mental health status and cognitive performance in male athletes.
4. To find an association among appetite hormones, mental health and cognitive performance with finger millet supplementation in male athletes.
5. To investigate and compare the impact of finger millet supplementation in male athletes and non-athletes, aiming to discern any significant differences in the outcomes between the two groups.

V. RESEARCH HYPOTHESIS

Null Hypothesis 1	Finger millet supplementation does not affect appetite-regulating hormones (ghrelin, leptin and cortisol) levels in male athletes.
Alternate Hypothesis 1	Finger millet supplementation affects appetite-regulating hormones (ghrelin, leptin and cortisol) levels in male athletes.
Null Hypothesis 2	Finger millet supplementation does not affect the mental health of male athletes.
Alternate Hypothesis 2	Finger millet supplementation affects the mental health of male athletes.
Null Hypothesis 3	Finger millet supplementation does not affect the cognitive performance of male athletes.
Alternate Hypothesis 3	Finger millet supplementation affects the cognitive performance of male athletes.
Null Hypothesis 4	There is no association between the Appetite Hormones, Mental Health and Cognitive Performance of male athletes.
Alternate Hypothesis 4	There is an association between the Appetite Hormones, Mental Health and Cognitive Performance of male athletes.
Null Hypothesis 5	There is no significant difference in the effects of finger millet supplementation between male athletes and non-athletes.
Alternate Hypothesis 5	There is a significant difference in the effects of finger millet supplementation between male athletes and non-athletes.

VI. REVIEW OF LITERATURE

The therapeutic application of nutritional interventions to enhance mental health is an emerging field of practice, revealing clear links between dietary choices and mental well-being. Rather than viewing mental and physical well-being as distinct entities, they should be regarded as interconnected facets of an individual's overall health. Indeed, one cannot thrive without the other when considering the holistic health of an individual *(Bradfield, 2021).*

Importance of Appetite Regulating Hormones

Diet and exercise are two major components of a lifestyle that influence appetite and energy metabolism in the body. The nutritional makeup of food, notably its macronutrient profile and fibre content, plays a pivotal role in shaping sensations of hunger, satiety, and overall appetite control. Consuming foods that are low in energy density, rich in fibre, low in fat, and paired with ample water intake fosters heightened satiety, concurrently reducing ghrelin levels and overall energy intake. This, in turn, can be a valuable strategy for the management of weight and metabolic issues *(Howe et al., 2014).*

Ghrelin

Ghrelin is a hunger hormone produced in the stomach that stimulates appetite and energy intake by the body. High ghrelin production leads to weight gain, metabolic disorders and depression *(Ozsoy et al., 2014).* High energy-dense, low-fibre, high-fat food is highly correlated with the excess production of ghrelin in the body *(Howe et al., 2014).* Injecting the Ghrelin hormone helps in increasing appetite and induces hunger which is a useful method in the treatment of anorexia nervosa without any adverse side effects *(Akamizu, 2008).*

A systematic review provides a comprehensive perspective on the relationship between exercise and ghrelin levels in athletes. The suppression of acyl ghrelin (AG) persisted beyond the conclusion of acute exercise, and this effect was independent of exercise intensity, contrary to previous assumptions. It also highlighted that increase in total ghrelin (TG) and des-acyl ghrelin (DAG) due to chronic exercise was more pronounced in overweight/obese individuals and with long-term exercise programs. Additionally, this review sheds light on the response of DAG to exercise, indicating that it increases with chronic but not acute exercise. These findings suggest

potentially beneficial changes in ghrelin levels associated with exercise, especially for metabolic health *(Ouerghi et al., 2021).*

Leptin

Leptin is a satiety hormone that is produced in the adipose tissue and is transported to the hypothalamus in the brain through the blood. The release of leptin is stimulated by insulin hence, whenever insulin will be released to metabolize glucose, leptin will also be released to induce satiety. Leptin signals the brain to suppress the appetite which provides the feeling of fullness and satiated. Hence, leptin plays a very important role in regulating the appetite and controlling energy intake by the body *(Ge et al., 2020; Brown et al., 2016; Klok et al., 2006).* Leptin also stimulates the release of GLP-1 hormone which also triggers satiety *(Zhang et al., 2016).*

Leptin hormone can be helpful in the treatment of depression as it is associated with the production of happy hormones and contributes to brain development *(Kara, 2018).* Low leptin production causes overeating and excessive hunger (hyperphagia) in obese people. Low leptin production is also seen in athletes who rely more on supplements or those who replace solid food with nutrition supplements to fulfil their nutritional needs *(Howe et al., 2014).*

The research found that as athletes underwent calorie-restricted diets and experienced a reduction in body mass, there was a significant decrease in blood leptin concentration. This means that as athletes lost weight through calorie restriction, their leptin levels decreased *(Holowko et al., 2019).* Lower leptin levels are often associated with increased hunger and reduced energy expenditure, which can make it challenging to maintain weight loss and appetite *(Holtzman and Askerman, 2019).*

Cortisol

The cortisol hormone produced by the adrenal gland is also known as the stress hormone. It serves to elevate blood glucose levels, ensuring an ample supply of glucose for the brain and other bodily organs to sustain their proper functionality during episodes of hypoglycemia. A glucose deficiency, whether due to hunger, stress, exercise or hormonal imbalances, prompts the production of cortisol. This hormone, in turn, stimulates cravings for high-calorie foods as a means to meet the body's escalating energy requirements. Cortisol further stimulates the production of ghrelin, commonly known as the 'hunger hormone,' which intensifies the craving

for high-calorie foods. These cravings are driven by the fact that high-calorie foods typically contain simple sugars, abundant carbohydrates, and fats, providing a swift means of replenishing the body's dwindling energy reserves *(Rahati et al., 2022).* When the food is subsequently ingested, the brain initiates the secretion of the leptin hormone, promoting a sense of satiety. Simultaneously, the release of dopamine, often referred to as the 'reward hormone,' elicits feelings of pleasure and contributes to the body's recovery from the stress state. This dual action orchestrated by cortisol indirectly aids the body in recuperating from stress, concurrently assisting in the stabilization of both blood pressure and blood glucose levels *(Yau and Potenza, 2013).*

Excessive cortisol levels can lead to Cushing's Syndrome, while cortisol deficiency can result in Addison's disease *(Nieuwenhuizen and Rutters, 2007)*. Consuming a diet rich in high-fibre, high protein, low carbohydrates, and low-fat foods effectively suppresses ghrelin while promoting the release of leptin and dopamine over an extended period *(Rahati et al., 2022).* Findings from a study on young endurance athletes reveal that cortisol levels surge when sleep duration declines, training intensifies, Heart Rate Variability during Nocturnal Rest (HRVNOC) declines, and the pressure of competition escalates *(Mishica et al., 2021).* The study found that a short-term Low Carbohydrate High Fat (LCHF) diet led to a significant increase in exercise-induced cortisol levels, indicating heightened stress response resulting in reduced exercise performance. However, with prolonged adherence to the LCHF diet, this cortisol response was attenuated, suggesting an adaptive effect over time *(Terink et al., 2021).*

Cognitive Performance of Athletes

The type of sport has a significant effect on different segments of cognitive performance in athletes. Physical activity and involvement in any kind of sporting activity have been shown effective in improving the cognitive performance of athletes. Athletes who had high cognitive performance tended to perform better in sports than those athletes who had comparatively low cognitive performance. Hence, the cognitive factor plays an important role in athletic performance *(Cona et al., 2015).* Mental fatigue also leads to poor cognitive performance in athletes *(Gantois et al., 2019).*

Analyses of cognitive functions with the mini-mental-state examination (MMSE) and Isaacs' Set Test of Verbal Fluency (IST) tests, brain derived neurotrophic factor (BDNF) and irisin levels in

the blood test of 26 athletes showed that athletes with high BDNF and irisin levels in their blood profile had better performance in cognitive tests as compared to the ones who had low BDNF and irisin blood serum levels *(Belviranli et al., 2016).* A meta-analysis by *Kalen et al. (2021)* stated that the less skilled athletes showed comparatively fewer cognitive functions (decision-making skills) as compared to the highly skilled athletes. Skill level was proved to be directly proportional to the cognitive function of the athletes.

Mental Health of Athletes

Athletes are highly prone to mental health disorders such as anxiety and depression as compared to the general or non-athletic population due to high exposure to more physical and mental pressure *(Rice et al., 2016).* Mental health concerns are very common among adolescent and college athletes. The pressure of the competition, training heavily, winning a medal, maintaining desired weight or physical health, disciplined life, supporting the family financially, injuries and homesickness during training and events add a lot of pressure on the athletes *(Gulliver et al., 2012).* Injuries, long training sessions, career termination and contract termination are the most common reasons behind increased mental health disorders in athletes *(Moesch, 2018; Rice et al., 2016).* Depression symptoms are observed higher in team sports and lower in individual sports. Team sports involve competition and comparison that adds additional stress on athletes *(McGuine, 2021).*

Stress, anxiety and eating disorders are very common mental health problems in athletes *(McNulty, 2001).* According to an experimental study, it was found that athletes were highly prone to stress and anxiety even with excellent physical activity sessions *(Rice, 2016).* Another study by *Gulliver, 2015* showed that about 46.4% of athletes experienced symptoms of mental health problems. Another study showed that 47.8% of athletes exhibit signs of anxiety and depression and 26.8% exhibit signs of stress *(Foskett and Longstaff, 2018).* Only with the improvement in their mental health, a significant improvement in their overall performance could be seen.

A study investigated the mental health status of elite athletes and found that both male and female elite athletes generally had better mental health compared to non-athletes across various measures. Team sport athletes displayed slightly better mental health than those in individual sports. Increased hours of physical exercise were associated with improved mental health and

higher life satisfaction, though excessively high training hours showed a decline in mental health among female athletes. Therefore, it is essential to strike a balance in physical activity to ensure that excessive exercise does not lead to a deterioration in mental well-being *(Grasdalsmoen et al., 2022).*

Effect of Nutrients on Mental Health Status (Stress, Anxiety and Depression) of Athletes

Nutrients present in food can affect the cognitive processes in the brain, influence emotions and modify mood by changing the chemical composition of our brain (Bayrami, 2020). The food consumed affects the production and release of neurotransmitters that trigger neural impulses and reactions that trigger a variety of moods. There is a direct relationship between the nutrition in our food, brain functioning and behaviour. Hence, any kind of nutrient deficiency has a direct role in mental health *(Banjari, 2014).*

High serotonin levels help in uplifting mood and a lack of serotonin is associated with a bad mood. Tryptophan supplementation, meditation, and aerobic exercise help in increasing serum serotonin and dopamine levels and uplift mood in athletes *(Young, 2007).* Iron is an important mineral that plays a major role in maintaining brain health. A deficiency of iron causes anaemia, shortage of oxygen supply in the brain and body and irritability. Tryptophan is an essential amino acid that provides a feeling of calmness and lack can cause depression *(Ekvall, 2005).*

In a study published in the *Indian Journal of Psychiatry*, it was explained that the people who had symptoms of depression were deficient in omega-3 fatty acids. The study indicated that daily supplementation of omega-3 fatty acids, vitamin B9, Vitamin B12 and essential amino acids were helpful in rapidly reducing the symptoms of depression and anxiety among athletes *(Rao, 2008).* Supplementation with alpha-tocopherol, folic acid, magnesium, omega-3 fatty acid, EPA and DHA were effective in reducing the symptoms of stress and anxiety among the athletic population because of their antioxidant and anti-inflammatory properties *(Muscaritoli, 2021).* A deficiency of omega 3 can lead to mood disorders. Hence, studies suggest supplementation of omega 3 daily could be a very effective therapeutic strategy for the treatment of mood and mental health problems *(Parker, 2006; Appleton, 2006; Rogers, 1996).*

Effect of Nutrients on Cognitive Performance of Athletes

Nutrition has an influential effect on the cognitive performance of athletes. Branched-chain amino acids increase serotonin production in the brain induce a happy mood and reduce post-workout stress and fatigue in athletes. Carbohydrate consumption with branched-chain amino acids showed improved cognitive performance post-exercise than only carbohydrate consumption without branched-chain amino acids *(Baker et al., 2014).* Carbohydrates improve the physical performance of athletes by improving endurance and reducing post-game fatigue. Carbohydrate is important to consume pre and during the game to improve cognitive function as brain cells need glucose for better functioning and cognitive tasks are highly useful in team sports which makes carbohydrate an even more important nutrient in team sports athletes' diet *(Baker et al., 2014).*

A randomized, double-blind experimental study by *Pomportes et al*. (2015) conducted on 56 athletes (32 males and 24 females) showed that consumption of multivitamins along with guarana fruit that contains caffeine showed improvement in decision-making performance along with stable autonomic nervous system regulation. Creatine supplementation helps in providing high amounts of energy to the brain in a short time which improves brain functioning and cognitive performance *(Meeusen and Decroix, 2017).*

The findings of an experimental study revealed that co-ingestion of impact of caffeine (CAF) and taurine (TAU) supplementation significantly improved cognitive performance, particularly in terms of reaction time. This suggests that the combination of CAF and TAU has a positive effect on the cognitive abilities of elite male boxers, potentially enhancing their decision-making, reasoning, and quick thinking during intense physical activities *(Ozan et al., 2022).*

Omega 3 fatty acids, carbohydrate supplementation and adequate hydration before and during exercise routines in athletes improve physical and cognitive performance in them. High-fat and high-sugar diets have a deteriorating effect on cognitive performance and can lead to neurodegenerative diseases. Carbohydrates, adequate nutrition and hydration before and during exercise have been shown to enhance brain function and cognitive performance in athletes *(Karpecka and Fraczek, 2020).*

Additionally, L-Theanine, beetroot juice, probiotics and creatine supplementation also help in improving mood and cognitive performance in athletes by improving their reaction time, working memory, accuracy, concentration, attention, alertness, speed, intelligence test results and reducing mental fatigue *(Szot et al., 2022).* An experimental study highlighted that beetroot juice (BJ) containing 400 mg of NO3 led to enhanced cognitive function in athletes *(Miraftabi et al., 2021).*

Benefits of Finger Millet

The nutrient-dense finger millet has a low glycemic index and helps maintain blood sugar levels. Its nutrient profile along with high fibre, amino acids, calcium, potassium, and antioxidant content helps in maintaining bone health, preventing high blood pressure, hypercholesteremia, obesity, breast cancer, childhood asthma, insulin resistance and celiac disease. It has slow gastric emptying rate and causes a slow release of glucose in the blood ensuring high nutrient absorption and healthy metabolism *(Verma and Patel, 2013).*

Finger millet stands out as a gluten-free grain, rendering it exceptionally gentle on the gastrointestinal tract. Its richness in dietary fibre not only contributes to the prevention of constipation but also supports the cultivation of a healthy gut microbiota *(Jagati et al., 2021).* Finger millet fosters gastrointestinal health by moderating the rate of gastric emptying, thereby promoting prolonged satiety. This aspect aids in appetite suppression, facilitating portion control and reducing overall calorie intake. Such dietary practices have been empirically associated with advantageous outcomes, including weight management, obesity prevention, and the maintenance of gut health. Its high calcium, iron, magnesium, phosphorus, copper, sodium and potassium levels make it useful in the treatment and prevention of bone and tooth-related diseases. High calcium content in finger millet can be helpful in maintaining bone strength, preventing bone problems and aid in faster recovery *(Jagati et al., 2021).*

Finger millet's high calcium (Ca) content makes it a valuable resource in preventing bone problems. This cereal surpasses other grains, containing three times more Ca than milk and ten times more than brown rice, wheat, or maize. Given that Ca is vital for bone health, regular consumption of finger millet can significantly contribute to preventing conditions like osteoporosis while enhancing bone strength. Additionally, finger millet's bioavailability of Ca, despite various factors affecting it, positions it as a promising, easily growing and low-cost

natural source of this essential nutrient. Therefore, incorporating finger millet into diets can play a crucial role in maintaining strong and healthy bones, especially in regions where Ca deficiency is a concern *(Puranik et al., 2017).*

Finger millet has antioxidant, antimicrobial, anti-ulcerative and anti-neuro-degenerative properties that help in preventing oxidative stress and ageing and aid in quick healing. It also possesses blood glucose lowering, nephroprotective properties, and cholesterol-lowering properties because of which if incorporated into the diet it reduces serum cholesterol and glucose levels. Germinated finger millet supplementation has proved to be effective against anaemia and its high iron content helps in improving haemoglobin levels in the blood *(Wadmare et al., 2022).*

Beneficial Effects of Finger Millet on Athletes – Hypothetical View

Incorporating finger millet into an athlete's diet, whether in the form of whole grains, flour, or processed products, can contribute to better energy management, enhanced recovery, and overall improved athletic performance considering their specific needs and training goals.

1. **Energy Source**: Finger millet is a rich source of complex carbohydrates *(Verma and Patel, 2013)*, providing athletes with sustained energy. These carbohydrates are essential for endurance, making finger millet an excellent choice for athletes engaged in long-duration sports or training.

2. **Appetite hormones:** Complex carbohydrates and high fibre diet have been proven to regulate appetite hormones by reducing hunger hormone ghrelin and increasing satiety hormone like leptin, GLP-1 and PYY by suppressing appetite (*Howe et al., 2014*). Therefore, complex carbohydrates and high fibre content of finger millet can be helpful in stimulating satiety hormones and supressing appetite.

3. **Mental health:** Satiety hormones like leptin, GLP-1 and PYY have been linked to stimulate happy hormones (Dopamine and serotonin) and reduce the levels of stress hormones like cortisol (*Clemente-Suarez et al., 2022*). High fibre content of finger millet would not only supress appetite and improves satiety levels by stimulating the production of satiety hormones but would also play an indirect role in stimulating happy hormones levels and improving mental health.

4. **Nutrient Density**: Finger millet is not only a carbohydrate source but also contains a variety of essential nutrients, including calcium, iron, magnesium, and amino acids *(Puranik et al., 2017).* These nutrients are crucial for overall health and can help athletes maintain their energy levels and support muscle function.

5. **Cognitive Performance:** Micronutrients play an important role in maintaining and improving cognitive function *(Szot et al., 2022)* and prevention of symptoms of anxiety, depression and neurodegenerative diseases *(Muscaritoli, 2021).* Therefore, high micronutrient profile such as magnesium, zinc, potassium, phosphorus and various other antioxidant and anti-inflammatory properties of finger millet would be helpful in improving cognitive performance of athletes.

6. **Muscle Recovery**: The amino acids in finger millet, such as methionine, play a role in muscle recovery and repair. Athletes can benefit from these amino acids, as they help reduce muscle soreness and aid in the regeneration of muscle tissue after intense workouts or competitions.

7. **Digestibility**: Finger millet is easily digestible, which can be advantageous for athletes before and after training or competition. Foods that are gentle on the digestive system can reduce the risk of gastrointestinal discomfort during physical activity.

8. **Gluten-Free**: Finger millet is naturally gluten-free, making it suitable for athletes with gluten sensitivities or celiac disease. It provides an alternative to gluten-containing grains like wheat, which can cause digestive issues for some individuals.

9. **Bone Health**: The calcium content in finger millet is beneficial for athletes, as it supports bone health *(Jagati et al., 2021)* and can help reduce the risk of stress fractures and other bone-related injuries common in sports.

10. **Weight Management**: Finger millet is relatively low in fat and calories, making it suitable for athletes looking to manage their weight while still obtaining essential nutrients for performance and recovery.

11. **Sustainability**: Finger millet is a sustainable crop with minimal environmental impact as it can easily grow in even harsh conditions with being pocket friendly *(Puranik et al.,*

2017). Athletes and sports organizations promoting sustainability may appreciate finger millet as an eco-friendly dietary choice.

12. **Dietary Diversity**: Incorporating finger millet into the dietary regimen of athletes not only introduces variety but also helps break the monotony often associated with their specific nutritional needs. Finger millet stands out as an exceptional and nutritious choice for athletes due to its versatility in complementing a wide range of flavours, making it a delicious and adaptable addition to their diets.

VII. METHODOLOGY

The present study is a randomized control trial to study the effect of finger millet supplementation on the appetite-regulating hormones, mental health and cognitive performance in male athletes.

Study Aim

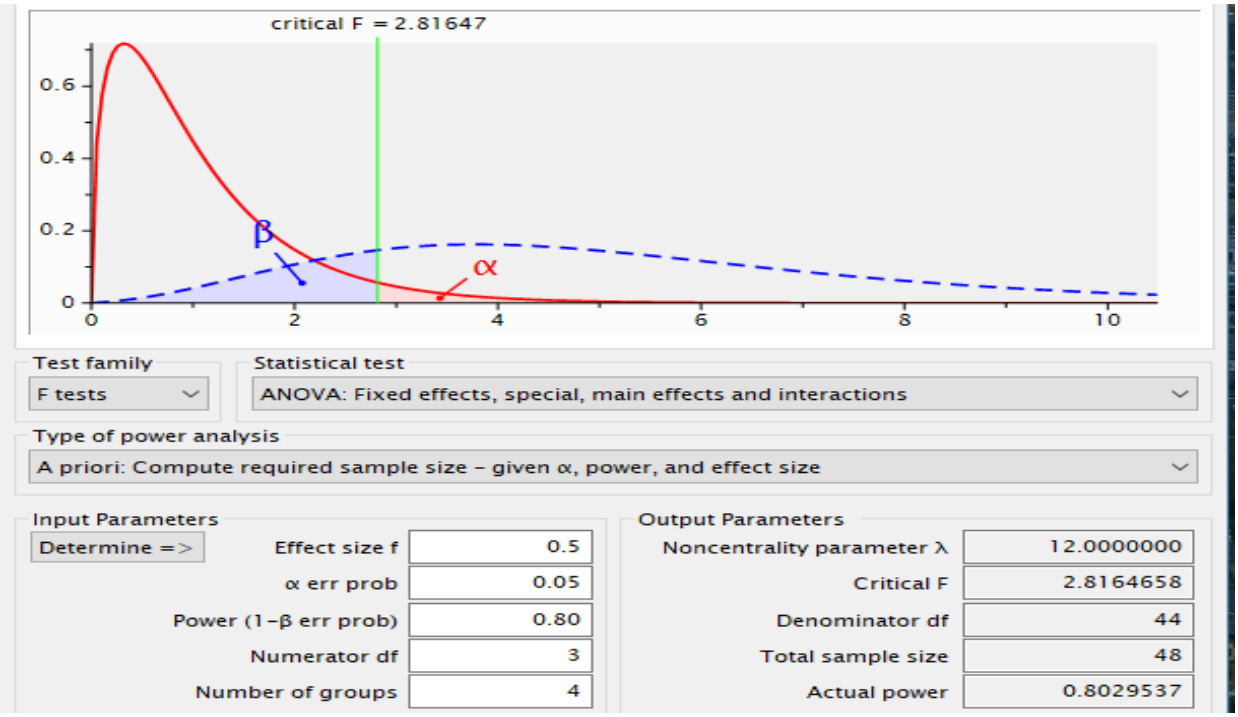
To study the comparative effect of finger millet supplementation on the appetite regulating hormones, mental health and cognitive performance in male athletes.

Study Area

The study will be conducted at Manav Rachna International Institute of Research and Studies and Manav Rachna University, Faridabad, Haryana.

Sample Size

The target sample (male athletes and non-athletes) will be identified through convenient purposive sampling. Male athletes (n=30) aged between 18-25 years undergoing general preparatory training in the preparatory phase will be recruited based on the screening test (Eating Attitudes Test; EAT-26) following the inclusion and exclusion criteria. Similarly, 30 non-athlete aged between 18-25 years would also be recruited. Based on the preliminary data, the 30 athletes and 30 non-athletes will be further randomly assigned to control and experimental groups. Each group will have 15 athletes and 15 non-athletes (Sample size =12 per sub-group as per calculation and total sample size of 48. Drop out of 20% = 3. Total group = calculated sample size + 20% drop out. Hence, 12 + 3 = 15 athletes in each subgroup. 15 athletes*4 sub-groups = 60 sample size).



2: Sample size calculation using G-Power

Inclusion Criteria: The inclusion criteria will be competitive healthy male athletes (for the athlete group) and non-athletes (for the non-athlete group) in the age range of 18-25 years and a willingness to either follow the trial guidelines (e.g., avoid potentially conflicting nutritional or vitamin supplements) or provide notification of compliance.

Exclusion Criteria: Consumption of millet, alcohol**,** smokers**,** any recent history of acute or chronic debilitating illness, medication, consumption of dietary supplements and ergogenic aids, physical disabilities**,** presence of sports injuries.

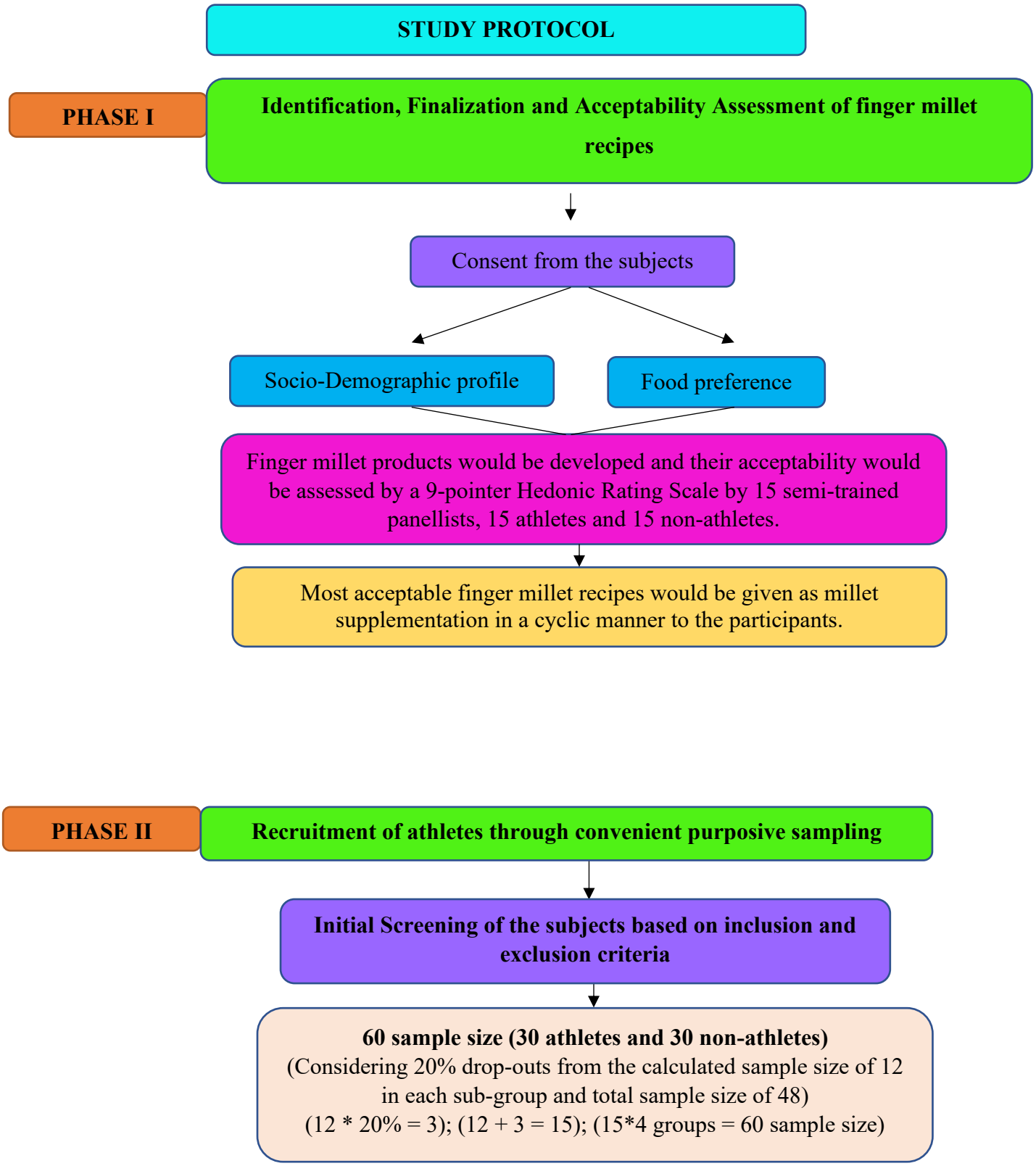
Institutional Ethical Committee: The participants will be briefed about the study and study protocol and their written consent will be taken. The consent of parents also will be obtained. The study protocol will be approved by the Institution Ethical Committee of Manav Rachna International Institute of research and Studies. All the procedures will be followed in accordance with the guidelines laid down in the declaration of Helsinki.

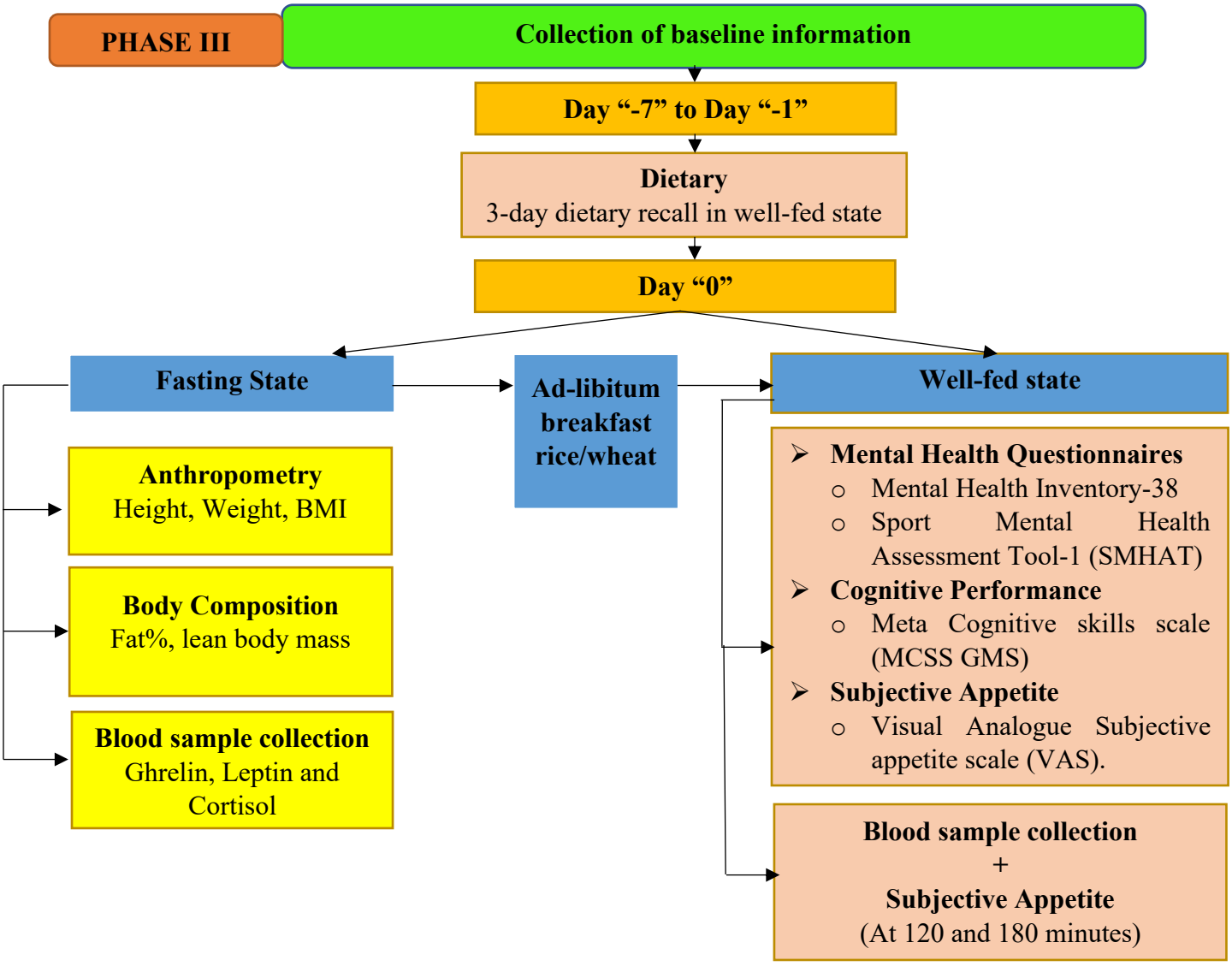
Study Design

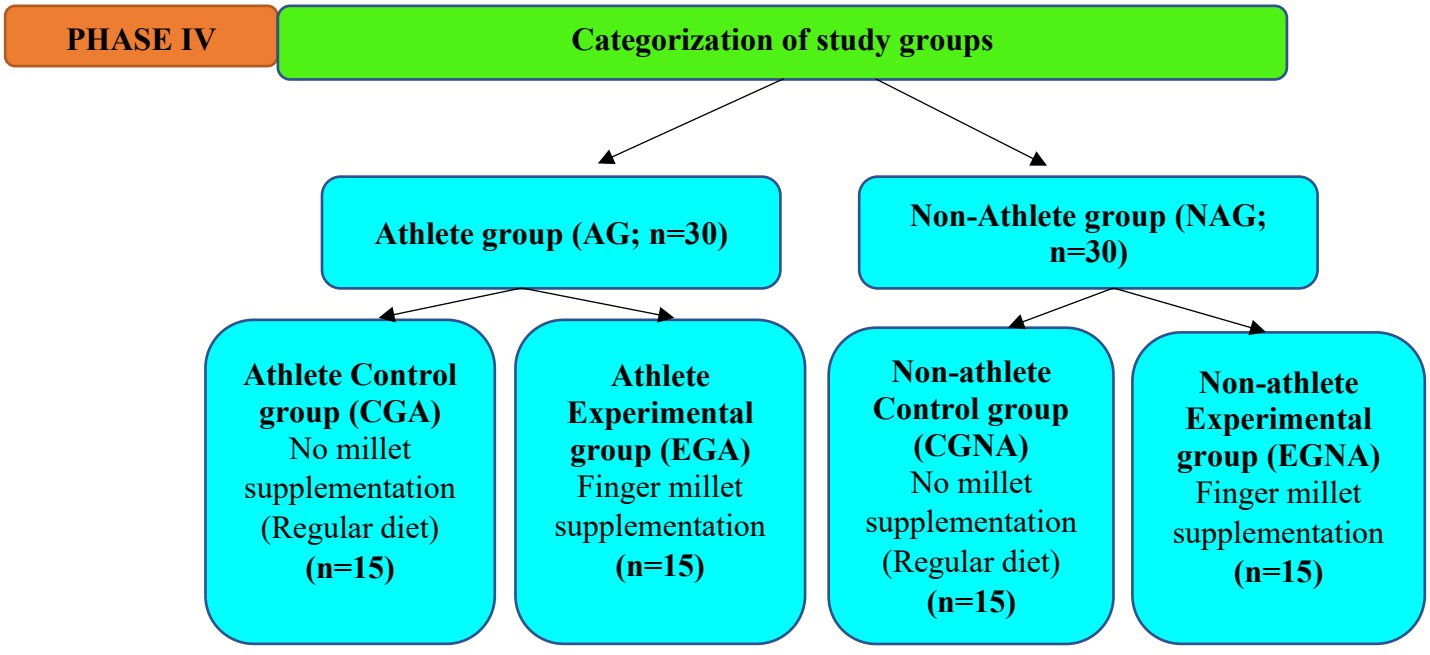
The study will be conducted in **six** phases.

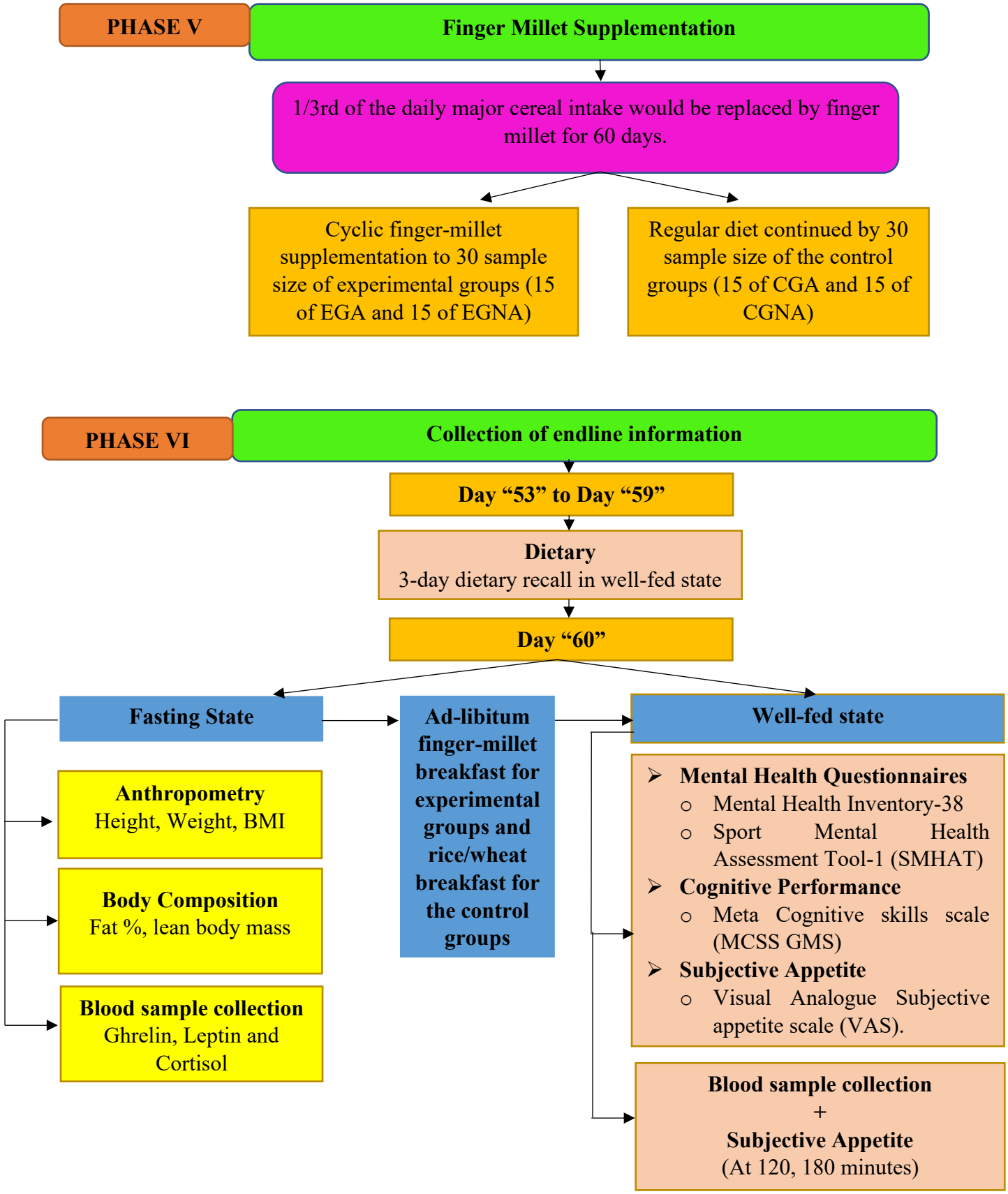
- **The First Phase** will involve the collection of information related to socio-demographic profile, food preference and acceptability of finger millet products from the athletes and non-athletes.
- **The Second Phase** will involve the recruitment of athletes. Male athletes (n=30) and non-athletes (n=30) aged between 18-25 years would be finalized. Athletes undergoing training in the general preparatory phase will be recruited through a convenient purposive method and based on the inclusion and exclusion criteria. Information related to socio-demographic characteristics, training years, phases and intensity will be elicited.
- **The Third Phase** will involve the collection of baseline information related to the outcome measures. Information collection on anthropometry and body composition and 3 days dietary intake will be done. The participants will be asked to refrain from exercise in the previous 24 hours and report to the laboratory after an 8 -12-hour fast on the day of the experiment. Upon reporting to the lab, a fasting blood sample will be taken for biochemical assessment. Then they will be asked to consume an ad-libitum breakfast (rice/wheat). Information on mental health and cognitive performance questionnaires will be collected in a well-fed state (post-meal consumption). Blood samples would again be collected at different time stamps: 120 and 180 minutes of the well-fed state. Information on satiety levels would also be collected through the VAS subjective appetite questionnaire at these time stamps.
- **The Fourth Phase** will involve the categorization of athletes and non-athletes into study groups. Based on the baseline data, athletes (n=30) or Athlete Group (AG) and non-athletes (n=30) or Non-Athlete Group (NAG) will be divided into two groups; Control Group: CGA and CGNA; (n= 15) in each group, Finger Millet Supplementation or Experimental Group: EGA and EGNA; (n=15) in each group through randomisation by minimisation. Minimisation will ensure a balance between the treatment groups to reduce bias. A random allocation of participants to the treatment groups would be performed. Information related to treatment groups will not be blinded to the investigator involved in diet management and will be blinded the during clinical assessments, and data analysis till the completion of assessments.

- **The Fifth Phase** will involve intervention with finger millet supplementation for a period of 60 days. A variety of finger-millet supplementation will be given cyclically to the experimental groups (EGA and EGNA) and the control groups (CGA and CGNA) would continue the regular rice /wheat-based diet. 3 days of cereal intake of randomly chosen 5 athletes and 5 non-athletes would be averaged. $1/3^{rd}$ of the daily major cereal intake would be replaced by finger millet daily for 60 days.
- **The Sixth Phase** will involve the collection of endline information related to the outcome measures. Information collection on anthropometry and body composition and 3 days dietary intake will be done for both study groups. All the participants will be asked to refrain from exercise in the previous 24 hours and report to the laboratory after an 8 - 12-hour fast on the day of the experiment. Upon reporting to the lab, a fasting blood sample will be taken for biochemical assessment. Then the participants of the Control Groups will be asked to consume ad-libitum regular food (rice/wheat) and the experimental groups will be given a finger millet-based diet. Information on mental health and cognitive performance questionnaires will be collected in a well-fed state (post-meal consumption). Blood samples would again be collected at different time stamps: 120 and 180 minutes of the well-fed state. Information on satiety levels would also be collected through the VAS subjective appetite questionnaire at these time stamps.


STUDY PROTOCOL
PHASE I
Identification, Finalization and Acceptability Assessment of finger millet recipes
Consent from the subjects
Socio-Demographic profile
Food preference
Finger millet products would be developed and their acceptability would be assessed by a 9-pointer Hedonic Rating Scale by 15 semi-trained panellists, 15 athletes and 15 non-athletes.
Most acceptable finger millet recipes would be given as millet supplementation in a cyclic manner to the participants.
PHASE II
Recruitment of athletes through convenient purposive sampling
Initial Screening of the subjects based on inclusion and exclusion criteria
60 sample size (30 athletes and 30 non-athletes)
(Considering 20% drop-outs from the calculated sample size of 12 in each sub-group and total sample size of 48)
(12 * 20% = 3); (12 + 3 = 15); (15*4 groups = 60 sample size)


PHASE III
Collection of baseline information
Day "-7" to Day "-1"
Dietary
3-day dietary recall in well-fed state
Day "0"
Fasting State
Ad-libitum breakfast rice/wheat
Well-fed state
Anthropometry
Height, Weight, BMI
Body Composition
Fat%, lean body mass
Blood sample collection
Ghrelin, Leptin and Cortisol
Mental Health Questionnaires
Mental Health Inventory-38
Sport Mental Health Assessment Tool-1 (SMHAT)
Cognitive Performance
Meta Cognitive skills scale (MCSS GMS)
Subjective Appetite
Visual Analogue Subjective appetite scale (VAS).
Blood sample collection
+
Subjective Appetite
(At 120 and 180 minutes)


PHASE IV
Categorization of study groups
Athlete group (AG; n=30)
Non-Athlete group (NAG; n=30)
Athlete Control group (CGA)
No millet supplementation
(Regular diet)
(n=15)
Athlete Experimental group (EGA)
Finger millet supplementation
(n=15)
Non-athlete Control group (CGNA)
No millet supplementation
(Regular diet)
(n=15)
Non-athlete Experimental group (EGNA)
Finger millet supplementation
(n=15)


PHASE V
Finger Millet Supplementation
1/3rd of the daily major cereal intake would be replaced by finger millet for 60 days.
Cyclic finger-millet supplementation to 30 sample size of experimental groups (15 of EGA and 15 of EGNA)
Regular diet continued by 30 sample size of the control groups (15 of CGA and 15 of CGNA)
PHASE VI
Collection of endline information
Day "53" to Day "59"
Dietary
3-day dietary recall in well-fed state
Day "60"
Fasting State
Anthropometry
Height, Weight, BMI
Body Composition
Fat %, lean body mass
Blood sample collection
Ghrelin, Leptin and Cortisol
Ad-libitum finger-millet breakfast for experimental groups and rice/wheat breakfast for the control groups
Well-fed state
Mental Health Questionnaires
Mental Health Inventory-38
Sport Mental Health Assessment Tool-1 (SMHAT)
Cognitive Performance
Meta Cognitive skills scale (MCSS GMS)
Subjective Appetite
Visual Analogue Subjective appetite scale (VAS).
Blood sample collection
+
Subjective Appetite
(At 120, 180 minutes)

Data Collection

The following section outlines the data which will be collected during the study period

1. **Socio-Demographic Profile-** Socio-Demographic profile data will be obtained through a short Multiple-Choice Question (MCQ) based questionnaire from the athletes.
2. **Product Acceptability-** Various finger millet products will be developed and their acceptability will be assessed through a 9-pointer hedonic rating scale by 15 semi-trained panellists, 15 athletes and 15 non-athletes. Highly acceptable products will be included in the study and will be given as supplementation to the athletes.
3. **Anthropometry and Body composition:** The body mass and height of athletes will be determined using standard procedures. Segmental body composition such as skeletal muscle mass (SMM), body fat mass, per cent body fat, visceral fat area (VFA), total body water (TBW), extra-cellular water (ECW) and intra-cellular water (ICW), protein and minerals will be taken using bio electrical impendence method following the standard protocols.
4. **Nutrient Intake:** The food intake pattern of athletes will be assessed using three days record method. This information is further converted to calories, macronutrients and micronutrient intake patterns based on the Indian Food Data Tables (IFCT), National Institute of Nutrition, Hyderabad.
5. **Biochemical Estimation:** Venous blood samples (3ml) from the antecubital vein will be taken at baseline and after 60 days- follow-up period after an overnight fast and after the training session. The samples will be taken into standard serum tubes, and centrifuged, and the serum will be collected, and stored at -20^0C for further analyses. Serum levels of ghrelin, leptin and cortisol will be measured using ELISA (Enzyme-Linked Immunosorbent Assay) tests.
6. **Mental Health Inventory-38:** The Mental Health Inventory (MHI) is used to assess psychological distress and well-being. It measures Stress, anxiety, and depression, measure include positive aspects of well-being (such as cheerfulness, interest in and enjoyment of life) as well as negative aspects of mental health (e.g. anxiety and depression).
7. **Sport Mental Health Assessment Tool-1 (SMHAT)-** This test is useful in determining the mental health status of athletes and indicates the presence or risk of developing any

mental health problem in them. This tool measures levels of anxiety, depression, sleep disturbance, substance abuse & eating disorder. Scores above 15 indicate severe anxiety and above 20 indicate severe depression.

8. **Cognitive performance:** Meta Cognitive Skills Scale (MCSS) developed by Gupta and Suman (2017) is a useful Likert-type five-point scale for the assessment of the level of meta-cognitive skills with 42 items under four dimensions i.e., Planning, Planning Skills, Implementation Skills, Monitoring Skills and Evaluation Skills.
9. **Subjective appetite**: Visual Analogue Scale (VAS) will be used to assess the subjective appetite, food intake, hunger and satiety. The scale consists of 6 questions with a rating on a measurable vertical line from not at all to extremely *(Flint, 2000).*

Data Analysis

Data analysis will be carried out using a statistical package for social sciences (IBM SPSS Version. 27.0, USA). Descriptive statistics will be carried out. Data will be subjected to normality tests using the Shapiro-Wilk test. Multivariate analysis of variance will be done to understand the association of various nutritional, biochemical and psychological variables. Qualitative aspects of the study will be analysed by manual coding and interpretation and for the questionnaire appropriate non-parametric tests will be employed.

Expected Study Outcomes

- The study will be able to identify acceptable finger millet products among athletes and non-athletes.
- It will help in identifying the effect of finger millet supplementation on appetite hormones, mental health and cognitive performance in athletes and non-athletes.
- The finger millet products could be recommended to athletes for better health and mental performance.
- The study would be able to provide the comparative effect of finger millet on athletes and non-athletes.
- The study will provide further direction for future research in this area.

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by Ekta Tanwar

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EFFECT OF FINGER MILLET SUPPLEMENTATION ON APPETITE REGULATING HORMONES, MENTAL HEALTH AND COGNITIVE PERFORMANCE IN MALE ATHLETES

SHORT SYNOPSIS

by

Ekta Tanwar

Registration number: 21/PhD/092

Under the supervision of

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ABSTRACT

The prolonged deprivation of dietary fibre, coupled with nutrient deficiencies and persistent stress leads to low levels of leptin hormone. This imbalance can cause the body to produce too much of the hunger hormone ghrelin and stress hormone cortisol. This hormonal imbalance fosters maladaptive behaviours such as emotional eating and food cravings, exacerbates irritability and compromises mental and cognitive performance among athletes. Finger millet is known to have functional properties that help prevent many health problems such as insulin resistance, high blood pressure, cancer and cardiovascular diseases increasing the period of gastric emptying and providing roughage to the gastro intestine. However, the health benefits of finger millet have not been explored in the athletic population. Hence, the present randomized control trial aims to study the effect of finger millet supplementation on appetite-regulating

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29th November, 2023

Dr. Kommi Kalpana
Supervisor
Professor, Sports Nutrition
Dept. of Nutrition and Dietetics, SAHS
MRIIRS
Faridabad- 121001

Dear Dr. Kommi Kalpana

The MRIIRS Ethics Committee has reviewed your request. for the ethical approval for the research project outlined below.

"EFFECT OF FINGER MILLET SUPPLEMENTATION ON APPETITE REGULATING HORMONES, MENTAL HEALTH AND COGNITIVE PERFORMANCE IN ATHLETES"

Ms. Ekta Tanwar
Research Schlor
Ph.D Programme, MRIIRS
Reg No:21/Ph.D./092

The case is discussed in the meeting of Ethical Committee, MRIIRS held on 31/10/2023 vide Online Mode at 9.30 AM.

https://meet.google.com/afw-bphq-hwz

Further, on examining the research work undertaken vide video presentation mode given by the research schloar, as indicated above, it was resolved that ethical approval may be granted as the research scholar will obtain consent of participants /subject i.e. athletes and non athletes. Also consent letter format / form both in English and Hindi are to be submitted.

The required documents as asked in the meeting have been submitted today i.e. 29.11.2023 by Prof. (Dr.) Kommi Kalpana, Supervisor, School of Allied Health Sciences, MRIIRS

Approval No:	EC/2023-24/040
Approval Date:	29/11/2023
Expiry Date:	28/11/2025
Ethics Committee Decision	Approved

The standard conditions of this approval are:

a) Conduct the project strictly in accordance with the proposal submitted and granted ethics approval. Including any amendments made to the proposal required by the MRIIRS Ethics Committee.
b) Report (email: dean.research@mriu.edu.in) immediately of any complaints or other issues in relation to the research project which may warrant review of the ethical approval of the project.
c) provide a 'progress report' for every year of approval.
d) provide a 'final report' when the project is complete.
e) advise in writing if the project has been discontinued

Please note that failure to comply with the conditions of approval and the **"INDIAN COUNCIL OF MEDICAL RESEARCH. 2017. NATIONAL ETHICAL GUIDELINES. FOR BIOMEDICAL AND HEALTH RESEARCH INVOLVING HUMAN"** may result in withdrawal of approval for the research project.

Sarita 29/11/23.

Dr Sarita Sachdeva
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